

provisional election made on February 19, 2002 to prosecute the claims of Group I (Claims 1-8). Non-elected Claims 9-13 have been canceled without prejudice.

Rejection of Claims 1 and 5 under 35 U.S.C. § 102(b) over Kraft *et al.*

Claims 1 and 5 are rejected under 35 U.S.C. § 102(b) over U.S. Patent No. 6,136,654 to Kraft *et al.* Initially, Applicants note that Claim 5 has been canceled. Therefore, Applicants respectfully submit that the rejection of this claim is now moot. With respect to Claim 1, Applicants respectfully traverse this rejection.

Claim 1 is directed to a method for forming a gate dielectric for an integrated circuit device. The method comprises the steps of: (a) forming an initial oxynitride layer upon a substrate material, the initial oxynitride layer having an initial physical thickness; and (b) subjecting the initial oxynitride layer to a plasma nitridation, the plasma nitridation resulting in a final oxynitride layer having a final physical thickness. It is a feature of the invention defined by Claim 1 that the final oxynitride layer has an equivalent oxide thickness of less than 15 angstroms and a nitrogen concentration of at least  $2.0 \times 10^{15}$  atoms/cm<sup>2</sup>. Applicants respectfully submit that this feature is not disclosed by Kraft *et al.*

The Kraft *et al.* patent is directed to a method of forming thin nitride or oxynitride gate dielectrics. The method comprises the following steps: (a) forming an oxygen-containing layer on a substrate; and (b) subjecting the oxygen-containing layer to a nitrogen-containing plasma so that the nitrogen is either incorporated into the oxygen-containing layer or forms a nitride layer at the surface of the substrate (col. 2, lines 39-43). The oxygen-containing layer may be an oxide layer, an oxynitride layer, or other insulating layer (col. 3, lines 53-54).

Kraft *et al.* fail to disclose that after subjecting this oxygen-containing layer to a nitrogen-containing plasma, the layer has an equivalent oxide thickness of less than 15 angstroms and a nitrogen concentration of at least  $2.0 \times 10^{15}$  atoms/cm<sup>2</sup>. For this reason, Applicants respectfully submit that Claim 1 is not anticipated by Kraft *et al.*, and therefore request withdrawal of this rejection.

Rejection of Claims 2-4 under 35 U.S.C. § 103(a) over Kraft *et al.*

Claims 2-4 are rejected under 35 U.S.C. § 103(a) as being unpatentable over Kraft *et al.* Initially, Applicants note that Claim 4 has been canceled. Therefore, Applicants respectfully submit that the rejection of this claim is now moot. With respect to Claims 2-3, Applicants respectfully traverse this rejection.

Claims 2 and 3 each depend from Claim 1. The method of Claim 1 comprises the steps of: (a) forming an initial oxynitride layer upon a substrate material; and (b) subjecting the initial oxynitride layer to a plasma nitridation, the plasma nitridation resulting in a final oxynitride layer. It is a feature of the invention defined by Claim 1 that the initial layer is an oxynitride layer, and it is a further feature that the final oxynitride layer has an equivalent oxide thickness of less than 15 angstroms *and* a nitrogen concentration of at least  $2.0 \times 10^{15}$  atoms/cm<sup>2</sup>. Applicants respectfully submit that this combination of features (at least) is neither disclosed nor suggested by Kraft *et al.*

As discussed above, the Kraft *et al.* patent is directed to a method of forming thin nitride or oxynitride gate dielectrics. The method comprises the following steps: (a) forming an oxygen-containing layer on a substrate; and (b) subjecting the oxygen-containing layer to a nitrogen-containing plasma so that the nitrogen is either incorporated into the oxygen-containing layer or forms a nitride layer at the surface of the substrate (col. 2, lines 39-43). Kraft *et al.* disclose that the oxygen-containing layer is “preferably either an oxide layer, an oxynitride layer, or other insulating layer” and more preferably an oxide layer (col. 3, lines 53-56). In every embodiment of Kraft *et al.*, an oxide layer is disclosed as the initial layer. Thus, Kraft *et al.* teach that an oxide layer is more preferable than an oxynitride layer as the initial layer, and therefore *teach away* from using an oxynitride layer as the initial layer.

Moreover, Kraft *et al.* fail to disclose or even suggest that the final layer, after being subjected to a nitrogen-containing plasma, has an equivalent oxide thickness (EOT) of less than 15 angstroms *and* a nitrogen concentration of at least  $2.0 \times 10^{15}$  atoms/cm<sup>2</sup>. It is well known in the art that when an oxide layer is subjected to a nitrogen-containing plasma, as taught by Kraft *et al.*, such that the final gate dielectric has a nitrogen concentration of at least  $2.0 \times 10^{15}$  atoms/cm<sup>2</sup>, the resulting gate dielectric will have an EOT of greater than 15 angstroms. To

achieve an EOT of less than 15 angstroms, after subjecting an oxide to a nitrogen-containing plasma using methods known in the art, the final gate dielectric will have a much lower nitrogen concentration. Prior to the present invention, an oxynitride gate dielectric having an EOT of less than 15 angstroms *and* a nitrogen concentration of at least  $2.0 \times 10^{15}$  atoms/cm<sup>2</sup> had not been achieved in the art.

Applicants have surprisingly discovered that when the initial layer is oxynitride rather than oxide, a final oxynitride layer is produced which has a substantially decreased thickness without compromising the high nitrogen concentration in the dielectric. Figures 5 and 6 of the present application demonstrate the superiority of oxynitride over oxide as the initial material (see page 6, line 10 – page 7, line 13). Figure 5 is a histogram for a population of gate dielectrics formed by subjecting an oxide to remote plasma nitridation (RPN), and Figure 6 is a histogram for a population of gate dielectrics formed by subjecting an oxynitride to RPN. In Figure 5, the mean EOT is approximately 16-17 angstroms, and in Figure 6, the mean EOT has been reduced to approximately 13-14.5 angstroms. Moreover, in Figure 6, the mean leakage current for a given EOT has been reduced by approximately 5 times that of the dielectrics of Figure 5, indicating a substantial increase in nitrogen concentration.

Kraft *et al.* fail to recognize the superiority of using an oxynitride rather than an oxide as the initial layer, and therefore fail to suggest that the final oxynitride layer has an EOT of less than 15 angstroms *and* a nitrogen concentration of at least  $2.0 \times 10^{15}$  atoms/cm<sup>2</sup>. Moreover, by teaching that it is more preferred to use oxide as the initial layer rather than oxynitride, Kraft *et al.* are actually teaching away from achieving the above EOT and nitrogen concentration in the final layer.

For this reason, Applicants respectfully submit that Claim 1 is patentable over Kraft *et al.* Claims 2 and 3, which include all the limitations of Claim 1, are also patentable over Kraft *et al.* Applicants therefore request withdrawal of this rejection.

Rejection of Claims 6 and 8 under 35 U.S.C. § 103(a) over Kraft *et al.* in view of Ito *et al.*

Claims 6 and 8 are rejected under 35 U.S.C. § 103(a) as being unpatentable over Kraft *et al.* in view of U.S. Patent No. 4,980,307 to Ito *et al.* Applicants respectfully traverse this rejection.

Claims 6 and 8 each depend from Claim 1. As discussed above, it is a feature of the invention defined by Claim 1 that the initial layer is an oxynitride layer, and it is a further feature that the final oxynitride layer has an EOT of less than 15 angstroms *and* a nitrogen concentration of at least  $2.0 \times 10^{15}$  atoms/cm<sup>2</sup>. Applicants respectfully submit that this combination of features (at least) is neither disclosed nor suggested by Kraft *et al.* in view of Ito *et al.*

Kraft *et al.* fail to disclose, and actually *teach away* from, a method wherein the initial layer is an oxynitride layer, and the final layer has an EOT of less than 15 angstroms *and* a nitrogen concentration of at least  $2.0 \times 10^{15}$  atoms/cm<sup>2</sup>. Ito *et al.* fail to remedy the deficiencies of Kraft *et al.* in this regard.

The Ito *et al.* patent is directed to a process for producing an oxynitride insulative film. The insulative film is formed by nitridation of an oxide film under a nitridation atmosphere containing nitrogen atoms (col. 4, lines 46-49). In all embodiments of Ito *et al.*, the initial layer is an oxide. Ito *et al.* fail to disclose or even suggest subjecting an oxynitride film to a plasma nitridation, and fail to disclose or suggest a final insulative film having an EOT of less than 15 angstroms *and* a nitrogen concentration of at least  $2.0 \times 10^{15}$  atoms/cm<sup>2</sup>. Ito *et al.* therefore fail to provide any motivation to modify the teaching of Kraft *et al.* in this regard.

Accordingly, Applicants respectfully submit that Claims 6 and 8, which include all of the limitations of Claim 1, are patentable over Kraft *et al.* in view of Ito *et al.* Applicants therefore respectfully request withdrawal of this rejection.

Claim 8 is patentable over Kraft *et al.* in view of Ito *et al.* for the following additional reason. It is a feature of the invention defined by Claim 8 that the final oxynitride layer has a reduction in effective electron mobility,  $\mu_{\text{eff}}$ , of less than 20% from the effective electron mobility of the initial oxynitride layer. Applicants respectfully submit that this feature is also neither disclosed nor suggested by Kraft *et al.* in view of Ito *et al.*

Kraft *et al.* fail to disclose or suggest anything about the effective electron mobility of their final layer with respect to their initial oxide layer. Since Kraft *et al.* teach away from using an oxynitride as the initial layer, and therefore fail to suggest that the final layer has an EOT of less than 15 angstroms *and* a nitrogen concentration of at least  $2.0 \times 10^{15}$  atoms/cm<sup>2</sup>, Kraft *et al.* also fail to suggest a final layer having the additional characteristic of a reduction in effective electron mobility,  $\mu_{\text{eff}}$ , of less than 20% from the effective electron mobility of the initial oxynitride layer.

Ito *et al.* fail to remedy the deficiencies of the Kraft *et al.* disclosure in this regard. Since Ito *et al.* fail to disclose or even suggest subjecting an oxynitride film to a plasma nitridation, Ito *et al.* therefore also fail to suggest a final layer having the additional characteristic of a reduction in effective electron mobility,  $\mu_{\text{eff}}$ , of less than 20% from the effective electron mobility of the initial oxynitride layer.

For this additional reason, Applicants respectfully submit that Claim 8 is patentable over Kraft *et al.* in view of Ito *et al.*, and therefore request withdrawal of this rejection.

Rejection of Claim 7 under 35 U.S.C. § 103(a) over Kraft *et al.* in view of Gousev *et al.*

Claim 7 is rejected under 35 U.S.C. § 103(a) as being unpatentable over Kraft *et al.* in view of Gousev *et al.*, "Growth and Characterization of Ultrathin Nitrided Silicon Oxide Film," IBM Journal of Research and Development, Vol. 43, No. 3, 1999, pp. 1-22. Applicants respectfully traverse this rejection.

Claim 7 depends from Claim 1. As discussed above, it is a feature of the invention defined by Claim 1 that the initial layer is an oxynitride layer, and it is a further feature that the final oxynitride layer has an EOT of less than 15 angstroms *and* a nitrogen concentration of at least  $2.0 \times 10^{15}$  atoms/cm<sup>2</sup>. Applicants respectfully submit that this combination of features (at least) is neither disclosed nor suggested by Kraft *et al.* in view of Gousev *et al.*

Kraft *et al.* fail to disclose, and actually *teach away* from, a method wherein the initial layer is an oxynitride layer, and the final layer has an EOT of less than 15 angstroms *and* a nitrogen concentration of at least  $2.0 \times 10^{15}$  atoms/cm<sup>2</sup>. Gousev *et al.* fail to remedy the deficiencies of Kraft *et al.* in this regard.

The Gousev *et al.* paper is directed to methods of forming and characterizing "ultrathin nitrided silicon oxide films." The title of this paper reveals that all oxynitride films discussed therein are formed by nitriding oxide films. In other words, the initial layer in all embodiments is an oxide layer. Gousev *et al.* fail to disclose or even suggest that the initial layer should be an oxynitride layer. Moreover, Gousev *et al.* fail to disclose or suggest a final oxynitride layer having an EOT of less than 15 angstroms *and* a nitrogen concentration of at least  $2.0 \times 10^{15}$  atoms/cm<sup>2</sup>. Thus, Gousev *et al.* provide no motivation to modify the teaching of Kraft *et al.* in this regard.

Accordingly, Applicants respectfully submit that Claim 7, which includes all of the limitations of Claim 1, is patentable over Kraft *et al.* in view of Gousev *et al.* Applicants therefore respectfully request withdrawal of this rejection.

No fee is believed to be due for the submission of this Amendment. However, if any fees are required, the Commissioner is authorized to charge such fees to Deposit Account No. 09-0458.

Respectfully submitted,

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Marked up Version of AmendmentsPursuant to 37 C.F.R. § 1.121(c)(1)In the claims:

Please amend the claims as follows:

1. (amended) A method for forming a gate dielectric for an integrated circuit device, the method comprising:

forming an initial oxynitride layer upon a substrate material, said initial oxynitride layer having an initial [physical] thickness; and

subjecting said initial oxynitride layer to a plasma nitridation, said plasma nitridation resulting in final oxynitride layer, said final oxynitride layer having a final [physical] thickness, wherein said final oxynitride layer has an equivalent oxide thickness of less than 15 angstroms and a nitrogen concentration of at least  $2.0 \times 10^{15}$  atoms/cm<sup>2</sup>.

2. (amended) The method of claim 1, wherein said final [physical] thickness exceeds said initial thickness by less than 5 angstroms.

3. (amended) The method of claim 1, wherein said final [physical] thickness is less than 20 angstroms.